15:58:25 OCA PAD AMENDMENT - PROJECT HEADER INFORMATION 08/17/94

Active

Project #: E-27-666 Cost share #: Rev #: 6
Center # : 10/24-6-R7651-0A0 Center shr #: OCA file #:
Work type : RES
Contract#: NAG 2-806 Mod #: BUDGET REVISION Document : GRANT
Prime #: Contract entity: GTRC

Subprojects ? : N CFDA: 43.002
Main project #: PE #: N/A

Project unit: TEXT ENGR Unit code: 02.010.130
Project director(s):
OLSON L H TEXT ENGR (404)894-2534

Sponsor/division names: NASA / AMES RESEARCH CTR, CA
Sponsor/division codes: 105 / 006

Award period: 921001 to 941231 (performance) 941231 (reports)

Sponsor amount	New this change	Total to date
Contract value	0.00	79,287.00
Funded	0.00	79,287.00
Cost sharing amount		0.00

Does subcontracting plan apply ?: N

Title: DESIGN & TECHNICAL SUPPORT OF DEVELOPMENT OF MOLDED FABRIC SPACE SUIT JOINT

PROJECT ADMINISTRATION DATA

OCA contact: Anita D. Rowland 894-4820

Sponsor technical contact	Sponsor issuing office
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EXTRA VEHICULAR SYSTEMS BRANCH,	UNIVERSITY AFFAIRS BRANCH, 241-1
239-15	MOFFETT FIELD, CA 94035-1000
MOFFETT FIELD, CA 94035-1000	

Security class (U,C,S,TS) : U ONR resident rep. is ACO (Y/N): N
Defense priority rating : N/A supplemental sheet
Equipment title vests with: Sponsor GIT X
NONE PROPOSED.
Administrative comments -
PROCESSED BUDGET REVISION DATED 8/15/94.

SR 426

GEORGIA INSTITUTE OF TECHNOLOGY
OFFICE OF CONTRACT ADMINISTRATION

NOTICE OF PROJECT CLOSEOUT

Closeout Notice Date 01/03/95

Project No. E-27-666 Center No. 10/24-6-R7651-0A0

Project Director OLSON L H School/Lab TEXT ENGR

Sponsor NASA/AMES RESEARCH CTR, CA

Contract/Grant No. NAG 2-806 Contract Entity GTRC

Prime Contract No. ______

Title DESIGN & TECHNICAL SUPPORT OF DEVELOPMENT OF MOLDED FABRIC SPACE SUIT JOI

Effective Completion Date 941231 (Performance) 941231 (Reports)

Closeout Actions Required:	Y/N	Date Submitted
Final Invoice or Copy of Final Invoice	Y	
Final Report of Inventions and/or Subcontracts	Y	
Government Property Inventory & Related Certificate	N	
Classified Material Certificate	N	
Release and Assignment	N	
Other	N	

Comments ______

Subproject Under Main Project No. ______

Continues Project No. ______

Distribution Required:

Project Director	Y
Administrative Network Representative	Y
GTRI Accounting/Grants and Contracts	Y
Procurement/Supply Services	Y
Research Property Managment	Y
Research Security Services	N
Reports Coordinator (OCA)	Y
GTRC	Y
Project File	Y
Other	N
	N

NOTE: Final Patent Questionnaire sent to PDPI.

E-27-666
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Design & Technical Support for Development of a Molded Fabric Space Suit Joint

Semi-annual Report #1

Period covered 10/1/92 - 3/31/93

Prepared for:

NASA Ames
Extra Vehicular Systems Branch
239-15
Moffett Field, CA 94035-1000
Technical Monitor: Hubert Vykukal

Prepared by:

Georgia Tech
School of Textile & Fiber Eng'g.
Atlanta, GA 30332-0295
Principal Investigator: L. Howard Olson

12/16/93

Semi-annual Report
Period covered 10/1/92 - 3/31/93

Design & Technical Support for Development of a Molded Fabric Space Suit Joint

12/16/93

Introduction

NASA Ames Research Center has under design a new elbow joint for use in a space suit. The design concept involves molding a fabric to a geometry developed at Ames. Unusual characteristics of this design include the need to produce a fabric molding draw ratio on the order of thirty percent circumferentially on the surface. Previous work done at NASA on molded fabric joints has shown that standard, NASA qualified polyester fabrics as are currently available for use in suits have a maximum of about fifteen percent draw ratio.

NASA has done the fundamental design of the elbow joint and of a mold which would impart the correct shape to the joint. NASA also has the capability to test a finished product for suitability and reliability. Other areas in the design effort are fiber selection and fabric design to achieve the objective, and determining production means and sources for the fabrics.

The immediate goals are to produce a prototype elbow joint using this design for evaluation of effectiveness by NASA, and to establish the sources, specifications, and test procedures which would allow reliable and repeatable production of the joint.

Description of Task

This task provides technical support for the textile design of a fabric for application to this joint design. As well, it covers design support in the prototype fabric development effort with respect to finding sources of small scale production, providing technical support to those sources during the developmental phase of work, and establishing the requisite procedures, specifications and test methods for the textile materials.

Research Progress

Prior success with polyester fabric and its approval by NASA led to searching for a polyester with the properties needed by this project. In a cooperative effort with Dr. Steve Hansen and Dr. Jim Howell of DuPont Fibers, Kinston, NC, a suitable candidate was found. The design goal was to achieve at least 28% elongation of the fiber such that molding draw could be tolerated by the fiber. The fiber finally prepared has the following 1properties:

Modulus:	(grams per denier)	70.2	
Tenacity:	(gpd)	3.8	
Elongation:	(%)	31.2	
Denier	(grams mass per 9km)	254	(nominal 250 denier)

At this point during the project, the fiber is in the hands of Fabric Development Inc. in Quakertown, PA.

Future Plans

The next step in the process is to manufacture fabric samples and have them tested at NASA Ames by Vic Vykukal. To this end, Dr. Olson will visit with Fabric Development with proposed reed plan, weave design and fabric design parameters needed for producing the samples.

E-27-666
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Design & Technical Support for Development of a Molded Fabric Space Suit Joint

Semi-annual Report #2

Period covered 4/1/93 - 9/30/93

Prepared for:

NASA Ames
Extra Vehicular Systems Branch
239-15
Moffett Field, CA 94035-1000
Technical Monitor: Hubert Vykukal

Prepared by:

Georgia Tech
School of Textile & Fiber Eng'g.
Atlanta, GA 30332-0295
Principal Investigator: L. Howard Olson

12/17/93

Semi-annual Report
Period covered 4/1/93 - 9/30/93

Design & Technical Support for Development of a Molded Fabric Space Suit Joint

12/17/93

Introduction

NASA Ames Research Center has under design a new elbow joint for use in a space suit. The design concept involves molding a fabric to a geometry developed at Ames. Unusual characteristics of this design include the need to produce a fabric molding draw ratio on the order of thirty percent circumferentially on the surface. Previous work done at NASA on molded fabric joints has shown that standard, NASA qualified polyester fabrics as are currently available for use in suits have a maximum of about fifteen percent draw ratio.

NASA has done the fundamental design of the elbow joint and of a mold which would impart the correct shape to the joint. NASA also has the capability to test a finished product for suitability and reliability. Other areas in the design effort are fiber selection and fabric design to achieve the objective, and determining production means and sources for the fabrics.

The immediate goals are to produce a prototype elbow joint using this design for evaluation of effectiveness by NASA, and to establish the sources, specifications, and test procedures which would allow reliable and repeatable production of the joint.

Description of Task

This task provides technical support for the textile design of a fabric for application to this joint design. As well, it covers design support in the prototype fabric development effort with respect to finding sources of small scale production, providing technical support to those sources during the developmental phase of work, and establishing the requisite procedures, specifications and test methods for the textile materials.

Research Progress

Fabric design and prototype sample weaving were the goals of this period. The basic concepts were to have a square or nearly square fabric design, i.e. one in which the number of warp ends per inch equalled the number of filling picks per inch. Fabric appearance and porosity are governed by the relation for fabric cover factor, namely the Cover Factor Relation is given as follows:

2(Note: This is an easily derived, traditional definition well known in textiles with which there is a great deal of experience.)

$$Cover\ Factor = \frac{E}{\sqrt{Cotton\ Count_E}} + \frac{P}{\sqrt{Cotton\ Count_P}}$$

Two more factors enter this part of the design. Firstly, because ends per inch, E, and picks per inch, P, are approximately the same, E and P are replaced by N, the number of yarns per inch in either fabric direction. Secondly, conversion from cotton count to denier is given by:

$$Cotton\ Count = \frac{5315}{Denier}$$

This means that cover factor may be rewritten as:

$$Cover\ Factor = N * \frac{\sqrt{Denier}}{36.45}$$

Due to large elongation of the fabric during the molding process, it is necessary to have a very tight fabric during the weaving process. The concept is that a tight cover factor will become a normal cover factor after molding deformation. The literature reports that tests with canvas or duck type looms have a weavability limit of about 36 in terms of cover factor value.

The fabric being woven in this instance for NASA is a tubular fabric whose diameter is just over five inches diameter. The prototype fabric is woven to the diameter of a gauge supplied by NASA which assures fit to the mold for which the fabric is being made. Heavy duck or canvas type looms are inappropriate for making this small flat width fabric, therefore a lower cover factor is needed than that which represents a heavy loom's weavability limit.

The denier of the polyester continuous filament yarn used for the first trials (reported in the previous semiannual report) is nominally 250 denier. A specimen was measured and found to be 254 denier. This is within normal tolerances for fiber manufacture. For calculations, the nominal value was used since shipments of polyester will oscillate in denier around the 250 value over the long term.

This means that values of cover factor and N can be tabulated.

cover factor	N
36	83
34	78
32	74
30	69

Past experience with fabric for NASA in a similar application shows that a finished value of 30 for cover factor is sufficient. Allowing for expansion of the fabric during molding and considering the maximum density of yarns practical in the reed, a final value of 80 ends per inch was chosen. Since looms cannot provide every integral value of picks per inch due to the drive gearing, some allowance is normally made about an optimum value. During weaving, samples were made at 57 picks per inch, but with difficulty in weaving. Therefore, a final fabric construction of 53 picks per inch. Here the ability to weave first quality fabric in a continuous run was a factor. The fabrics had areal densities of 4.7 oz./yd^2 (57 ppi) and 4.6 oz./yd^2 (53 ppi).

Future Plans

Tests of the first fabric samples show that friction in the mold, most likely, leads to nonuniform distribution of fiber elongation. Thus, a 250 denier yarn with 45 - 50% elongation is to be procured in the second iteration of the design process. A final iteration may be needed to optimize weaving efficiency against finished fabric cover factor.

E-27-666
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Design & Technical Support for Development of a Molded Fabric Space Suit Joint

Final Report

Period covered 10/1/92 - 12/31/94

Prepared for:

NASA Ames
Extra Vehicular Systems Branch
239-15
Moffett Field, CA 94035-1000
Technical Monitor: Hubert Vykukal
NASA Grant # NAG 2-806

Prepared by:

Georgia Tech
School of Textile & Fiber Eng'g.
Atlanta, GA 30332-0295
Principal Investigator: L. Howard Olson
Ga. Tech Project No. E27-666

12/21/94

Final Report
Period covered 10/1/92 - 9/30/93

Design & Technical Support for Development of a Molded Fabric Space Suit Joint

NASA Grant # NAG 2-806
Ga. Tech Project No. E27-666

12/21/94

Introduction

NASA Ames Research Center has under design a new joint or element for use in a space suit. The design concept involves molding a fabric to a geometry developed at Ames. Unusual characteristics of this design include the need to produce a fabric molding draw ratio on the order of thirty percent circumferentially on the surface. Previous work done at NASA on molded fabric joints has shown that standard, NASA qualified polyester fabrics as are currently available in the textile industry for use in suits have a maximum of about fifteen percent draw ratio.

NASA has done the fundamental design for a prototype joint and of a mold which would impart the correct shape to the fabric support layer of the joint. NASA also has the capability to test a finished product for suitability and reliability. Responsibilities resting with Georgia Tech in the design effort for this project are textile related, namely fiber selection, fabric design to achieve the properties of the objective design, and determining production means and sources for the fabrics.

The project goals are to produce a prototype joint using the NASA design for evaluation of effectiveness by NASA, and to establish the sources and specifications which would allow reliable and repeatable production of the joint.

Description of Task

This task provides technical support for the textile design of a fabric for application to the NASA joint design. As well, it covers design support in the prototype fabric development effort with respect to finding sources of small scale production, providing technical support to those sources during the developmental phase of work, and establishing the requisite procedures and specifications for the textile materials.

Research Results

Fiber selection

Prior success with polyester fabric and its approval by NASA led to searching for a polyester with the properties needed by this project. In a cooperative effort with Dr. Steve Hansen and Dr. Jim Howell of DuPont Fibers, Kinston, NC, a suitable candidate was found.[1] The design goal was to achieve at least 28% elongation of the fiber such that molding draw could be tolerated by the fiber. The initial fiber prepared by DuPont noted as type TPEX-566 has the following yarn properties:

Modulus:	(grams per denier)	70.2	
Tenacity:	(gpd)	3.8	
Elongation:	(%)	31.2	
Denier	(grams mass per 9km)	254	(nominal 250 denier)

Later in the project as will be explained in the following, a second yarn was produced specially for the NASA tasks by DuPont. This is identified as 150-34-type 56 with an ID number of DRT-3-0095. This second yarn is 150 denier and has about 50% elongation. This was done to resolve a problem of tearing during molding which was caused by non-uniform distribution of elongation in the mold. Friction at angles while the fabric is loaded by the molding process account for this problem. The 31.2% elongation of the first fiber allowed about 3 - 4% for this effect, but this was not enough.

Fabric selection

The commercial production of fabric has been the responsiblility of Fabric Development Inc., 1271 Mill St., Quakertown, PA 18951.[2]

Fabric design and prototype sample weaving goals of this project have been met quite satisfactorily. The basic concept normally is to have a square or nearly square fabric design, i.e. one in which the number of warp ends per inch equalled the number of filling picks per inch. This was changed in this project due to

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[1]Dr. Hansen is at (919)522-6692, and Dr. Howell is at (919)522-6882. The fax at the lab where both work is -6597.

[2]The contact person at Fabric Development is Jean Martin, phone (215) 536-1420, fax -1154.

special circumstances which are noted later.

To illustrate the terms warp and filling as used above, a figure has been included. Figure 1. has warp yarns running vertically and filling yarns horizontally in a plain weave pattern.

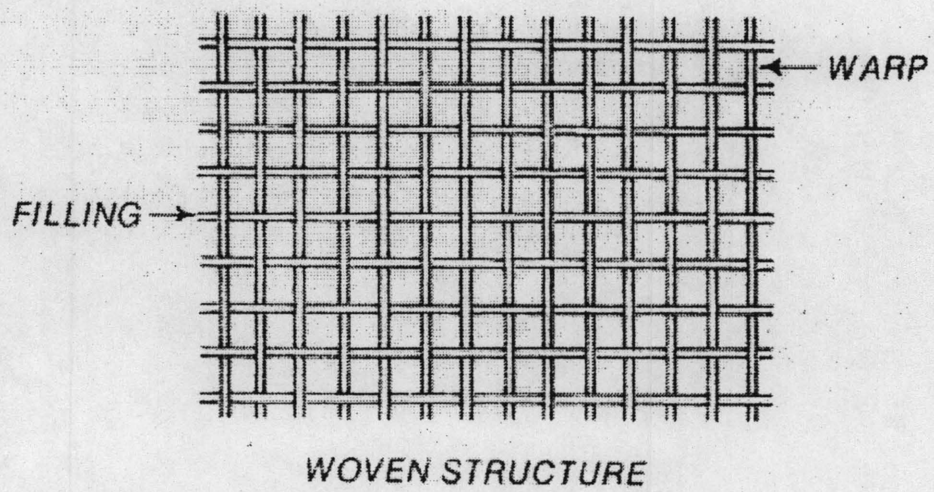

Figure 1 Plain Weave Fabric

Plain woven fabric has been shown in research done for the U.S. Army at Ft. Belvoir to provide the greatest tensile strength. This is due to maximum load sharing due to maximum number of interlacing points. While special twill and satin weaves (with fewer interlacing points) do provide greater tear strength, they do so at a loss of tensile strength. From a design point of view, the fabric of this project will be protected by an exterior covering such that this element is protected from external snagging or other tearing forces. From a safety point of view, the fabric will be loaded to no more than 25% of ultimate strength, therefore it will have more than adequate tear strength and, more importantly, no inclination to spontaneous crack propogation which was the primary concern in the Ft. Belvoir research.

Cover factor

Fabric appearance and porosity are governed by the yarn spacing of yarns practical in the reed, a final value of 80 ends per inch has been chosen. Since looms cannot provide every integral value of picks per inch due to the drive gearing, some allowance is normally made about an optimum value. During weaving, samples were made at 57 picks per inch, but with difficulty in weaving (weave limit). Therefore, a final fabric construction of 53 picks per inch is selected. Here the ability to weave first quality fabric in a continuous run is a factor. The fabrics have areal densities of 4.7 oz./yd^2 (57 ppi) and 4.6 oz./yd^2 (53 ppi).

Noting that cotton is 14.9% denser than cotton, yet polyester normally has less crimp, it is difficult to estimate the precise effect of volume differences on cover factor. A calculation of cover factor for these two fabrics is:

80 X 57 = 29.7 with density difference = 34.1

80 X 53 = 28.8 with density difference = 33.2

The loss of cover factor due to molding the fabric to shape is about 3 - 4. Judging from appearance of the final molded fabric, the higher figure (to the right of each line above) which includes density is probably correct.

The second lot of fabric used a polyester was made specially and uniquely for NASA. It has an elongation of 50%. Due to production availability or limitations it was delivered in 150 denier. To approach the same conditions as were available with the first yarn lot, this yarn was two plied into a 300 denier yarn with about two turns of Z twist. Keeping the warp part of the cover factor the same as that of the 80 X 53 fabric, which is 17.53, the new fabric was held to the same warp cover. This gave 74 ends per inch in the fabric.[4] Then matching the total cover factor to that achieved previously gives 48 picks per inch.

This fabric has been produced and delivered. Further work on this will be done in later efforts.

Air retaining member

The only other fabric need might be a reinforcement scrim for use

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[4]The loom reed requires about 5% more spacing than will be achieved in the final fabric. Considering this and using four ends per dent yields a 35.24 dent loom reed.

with a bladder type structure. This fabric may be a leno woven material much resembling a gauze type fabric. The leno weave would be particularly useful in giving dimensional stability to the fabric during molding operations.

The bladder material preferably is a polyurethane. Efforts with three sources to find a suitable (low durometer and pliable) type of urethane has met with some difficulty. The trend in urethane products is toward hard rubbers, such as might be used in wheels and casters. Less R&D in this business has led to less opportunity to sample specialty versions of urethanes.

Conclusions and Recommendations

The fabric made from type 56 polyester specially for this project has the performance characteristics needed for the molding operation. Using a two ply structure for a net 300 denier yarn gives appropriate cover and appearance for this application. This effort had as its goal to find the materials and weaving method to produce the fabric for initial evaluation. That goal has been met.

Future work should look into the problems of producing a tapered woven section for introduction of a tapered molding process. Then the quality control and production methods need to be written to assure consistency with general commercial procurement of these materials.